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Visual Indicator-Stonefish
Exercise Mine, Polymeric
Materials Selection

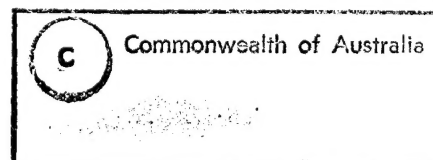
R.J. Roseblade

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R.J. Roseblade

**Ship Structures and Materials Division
Aeronautical and Maritime Research Laboratory**

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ABSTRACT

The RAN has a requirement for a real time visual mine firing indicator (VISEM) for the Stonefish Exercise Mine (SEM). This device is an alternative indicator to the towed receiver which is not available to all ships that exercise with the SEM due to its limited availability and high cost.

This report documents aspects concerning the choice of polymeric materials for the VISEM. A design profile was drawn up and the critical parameters used in the PLASCAMS 'Plastics Computer Aided Materials Selector' program to indicate suitable plastics materials for production of components of the VISEM. Acrylonitrile Butadiene Styrene (ABS) was selected as having the optimum properties to meet the design profile that included requirements for hydrolytic stability, toughness over a wide temperature range and ease of production by injection moulding and assembly with adhesives.

The report also includes information about other polymers and adhesives used in the device including some used to test concepts or selected as a matter of expediency during the development phase of the project.

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Visual Indicator-Stonefish Exercise Mine, Polymeric Materials Selection

Executive Summary

This report describes the process used to select various polymeric materials for the manufacture of a visual indicator device to be used as an accessory to the Stonefish Exercise Mine (SEM).

The RAN acquired a number of SEM's for use in training exercises for mine detection and clearance. These can be used in one of two modes; cable controlled or free mode. In the free mode communication with the SEM is established when it emits an acoustic signal in response to a passing ship which can be recorded by ships in the area via an 'in-water' towed receiver. The mine firing acoustic signal registers on a display in the ship's bridge to tell the commanding officer that the mine has 'fired'. The limited availability and high cost of the towed receiver precludes the fitting of this equipment to all ships that exercise with the SEM. Consequently ships without the benefit of the 'in-water' electronics must rely upon receiving the results of the mine data transmission messages from other ships. The delay in notifying the recipient, and other ships, that a critical mine encounter may have occurred, causes a significant lack of realism and concern to participating ships and to the overall value of the training exercise. Consequently the RAN identified a requirement for a real time visual mine firing indicator, i.e. Visual Indicator Stonefish Exercise Mine (VISEM), which would indicate to all the ships in the exercise that an SEM had transmitted a simulated detonation signal. AMRL (Maritime Operations Division) undertook to develop the VISEM over a three year period, to a stage suitable for manufacture by Industry for the RAN.

The VISEM system is attached to the SEM by an external tether at deployment and is designed to float about 2 m above the SEM after it lodges on the ocean floor. The recommended indicator system consists of five Surface Position Markers (SPM) housed in separate compartments of a cradle that also includes a power supply module and an electronics module. On receipt of an acoustic signal from the SEM, indicating that it has been triggered by a passing ship, the VISEM releases one SPM that floats to the surface. At this point a flare ignites and a sequence of three photo flashes is ejected to a height of 4 m where they sequentially explode giving a sound and light signature. The flare continues to burn for about 20 s emitting a bright yellow/orange plume that is to be visible for a minimum of 3000 m. The remaining SPM's in the VISEM can be released by the passage of further ships during the deployment period. At the end of the operational time the VISEM, together with unused SPM's, can be recovered when the SEM is floated to the surface. Expended SPM's remain attached to the VISEM by

their tether lines and are also recovered at this time. The operational lifetime of the VISEM under exercise conditions is 90 days.

Production costs are to be competitive since annual usage by the RAN is estimated at 200 and there is a possibility of an export market. This indicated the need for relatively cheap, readily available plastics materials for the casing, which could be produced by a process such as injection moulding, and the components assembled by the use of adhesives.

To select the optimum plastics materials for construction of the VISEM the PLASCAMS 'Plastics Computer Aided Materials Selector' program was used.. From the design profile a list of parameters was compiled for use in the program on a single property search basis for thermoplastic materials. Five materials (from a data base of 351) remained after the seventh search, these consisting of various grades of Acrylonitrile Butadiene Styrene (ABS) which is a readily available, cheap, engineering grade thermoplastic. A large range of available grades offered ample scope for 'fine tuning' depending on which material attributes became significant during the development phase of the project. The choice of ABS was supported by a creditable performance of the material in subsequent sea trials of the VISEM.

The VISEM is assembled with adhesives and contains a number of plastics materials, other than ABS, some of which were used in the development phase as a matter of expediency. Details of these are given in the report, along with an outline of the function which the various components are required to fulfil, and any shortcomings encountered during the proving trials. This information will enable an informed choice of material to be made for the production phase when other factors such as the number to be produced will influence material choice.

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1. Introduction

The RAN requirement for a visual mine firing indicator for the Stonefish Exercise Mine (SEM) was originally outlined in [1] while background information relating to the requirement was given in [2] as follows:

The RAN acquired a number of SEM's for use in training exercises for mine detection and clearance. The SEM emits an acoustic signal in response to a passing ship which can be recorded by ships in the area via an 'in-water' towed receiver. The mine firing acoustic signal registers on a display in the ship's bridge to tell the commanding officer that the mine has 'fired'. The limited availability and high cost of the towed receiver precludes the fitting of this equipment to all ships that exercise with the SEM. Consequently ships without the benefit of the 'in-water' electronics must rely upon receiving the results of the mine data transmission messages from other ships. The delay in notifying the recipient, and other ships, that a critical mine encounter may have occurred, causes a significant lack of realism and concern to participating ships and to the overall value of the training exercise.

Consequently, the RAN identified a requirement for a real time visual mine firing indicator, i.e. Visual Indicator Stonefish Exercise Mine (VISEM), which would indicate to all the ships in the exercise that an SEM had transmitted a simulated detonation signal. Thus the proposed VISEM system was required to generate a visual and audible signal of sufficient magnitude to unequivocally indicate that the SEM had been initiated and indicate the proximity of the SEM to that vessel.

AMRL (Maritime Operations Division) undertook to develop the VISEM, over a three year period, to a stage suitable for manufacture by Industry for the RAN. This report documents aspects concerning the choice of polymeric materials for the device.

2. Design Profile

The VISEM system is attached to the SEM by an external tether at deployment and is designed to float about 2 m above the SEM after it lodges on the ocean floor. The recommended indicator system consists of five Surface Position Markers (SPM) housed in separate compartments of a cradle that also includes a power supply module and an electronics module as shown by Figure 1. On receipt of an acoustic signal from the SEM, indicating that it has been triggered by a passing ship, the VISEM releases one SPM that floats to the surface. At this point a flare ignites and a sequence of three photo flashes is ejected to a height of 4 m where they sequentially explode giving a sound and light signature. The flare continues to burn for about 20 s emitting a bright yellow/orange plume that is to be visible for a minimum of 3000 m. The remaining SPM's in the VISEM can be released by the passage of further ships during the deployment period. At the end of the operational time the VISEM, together with unused SPM's, can be recovered when the SEM is floated to the surface. Expended

SPM's remain attached to the VISEM by their tether lines and are also recovered at this time. The operational lifetime of the VISEM under exercise conditions is 90 days.

A depth range of 15 m to 90 m and a design temperature range of -10°C to $+55^{\circ}\text{C}$ is required. The flare composition is to be contained in a cardboard cylinder so that direct contact with the plastics case is precluded. After it has reached the surface and the plastics cap on the VISEM has been removed by internal pressure from the ignition sequence, the flare burns for 20 s at a temperature around 2000°C . It is a desired feature (unlikely to be achieved in practice) that the burning flare composition will consume the casing and/or buoyancy jacket (float) causing only a small remnant of the flare to sink, thus avoiding the potential environmental problems that might arise from debris being washed ashore.

Production costs are to be competitive since annual usage by the RAN is estimated at 200 and there is a possibility of an export market. This indicated the need for relatively cheap, readily available plastics materials for the casing, which could be produced by a process such as injection moulding, and the components assembled by the use of adhesives.

3. Plastics Material Selection

A reasonable choice of plastics material for a particular application can usually be made with experience alone. However it is more effective to apply experience in a systematic way using one or more of the various published or computer aided selection guides that are available. In this case the PLASCAMS 'Plastics Computer Aided Materials Selector' program [3] was used to indicate suitable plastics materials for production of selected parts of the VISEM. From the design profile a list of parameters was compiled, as shown in Table 1, for use in the program on a single property search basis for thermoplastic materials. Specific parameter values were used in the program where possible, otherwise value judgements on a 0-9 scale were used where a value of 0 indicates that the material does not possess the property in question, and a value of 9 indicates that the property is well represented. In searching for the top 50 % of materials, value judgements in the range 5-9 would be specified.

ITEM No.	DESCRIPTION
1	BASE PLATE & CENTRE TUBE ASSY.
2	SPM. ASSY. (2-VARIANTS)
3	POWER SUPPLY ASSY.
4	ELECTRONICS HOUSING ASSY.
5	MOORING
6	SPM. LEAD/CONNECTOR ASSY.
7	POWER SUPPLY LEAD/CONNECTOR ASSY.
8	CONTAINER BODY
9	CONNECTOR
10	MOUNTING FRAME
11	FRAME ATTACHING BRACKET

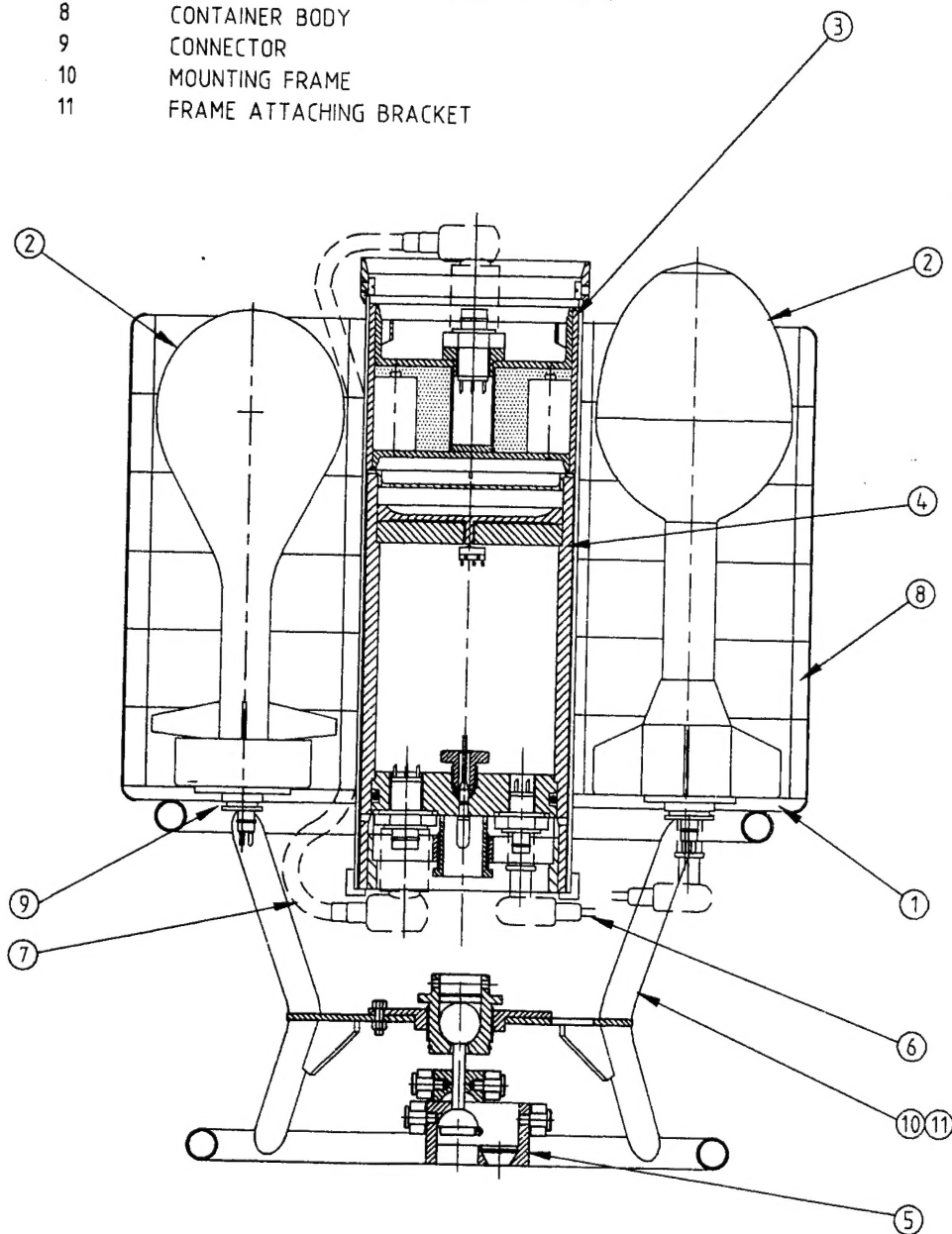


Figure 1: VISEM Assembly [8].

Table 1: VISEM Design Parameters for use in the PLASCAMS Plastics Computer Aided Materials Selector

Search No.	Category	Property	Value 0-9 or Specific	Materials Listed
1	(4) Prod. method	Injection moulding	6-9	123
2	(5) Post processing	Bonding	6-9	51
3	(3) Chem.& rad. resist.	Hydrolytic stability	7-9	38
4	(1) Gen.& electrical	Heat distort. temp.	55°C	33
5	(2) Mechanical props.	Toughness at 20°C	5-9	19
6	(2) Mechanical props.	Tensile strength	> 35 MPa	15
7	(2) Mechanical props.	Brittle temperature	6-9	5

It can be seen from Table 1 that five materials (from a data base of 351) remained after the seventh search, these consisting of various grades of Acrylonitrile Butadiene Styrene (ABS).

4. Acrylonitrile Butadiene Styrene (ABS) Technical Details

ABS is a readily available, cheap, engineering grade thermoplastic. It consists of styrene-acrylonitrile copolymer as a continuous phase, with a dispersed phase of microscopic polybutadiene rubber particles onto which styrene-acrylonitrile copolymer has been grafted. Through variations in composition, molecular weight, and morphology of the rubber phase, these materials can be tailored to exhibit a very wide range of properties. ABS can also be blended (alloyed) with other polymers to achieve some of the superior properties of each of the constituents (e.g. nylon, PVC, polycarbonate) or copolymerised with additional monomers (eg, methylmethacrylate, alphamethylstyrene).

The PLASCAMS data sheet for ABS (high impact) is shown by Table 2.

Table 2: PLASCAMS data sheet (ABS high impact)

Resin type	T.P. amorp.	Cost per tonne	\$3200
		SG	1.03
Max. operating temp.	70°C	Surface hardness	102RR
Water absorption	0.3 %	Linear expansion	9*10-5
Tensile strength	38 MPa	Flammability (UL94)	HB
Flexural modulus	2.2 GPa	Oxygen index	19 %
Elongation at break	8 %	Volume resistivity	16 log ohm cm
Notched izod	0.4 kJ/m	Dielectric strength	25 MV/m
Heat distortion temp. (0.45 MPa)	98°C	Dielectric const. (1 kHz)	2.8
Heat distortion temp. (1.80 MPa)	89°C	Dissipation factor (1kHz)	0.007
Material drying	2 h at 90°C	Melt temp. range	230-270°C
Mould shrinkage	0.7 %	Mould temp. range	40-60°C

The PLASCAMS text describes ABS as follows:

Advantages: Hard for a thermoplastic. Reasonably tough (maintains impact resistance to low temperatures). Easily processed (may be electroplated), easily bonded. Good gloss, surface scuff resistant. Low shrinkage and warpage.

Disadvantages: Poor solvent and fatigue resistance. Poor U.V. resistance, unless protected. Maximum continuous use temperature 70°C. Poor bearing properties (high friction and wear). High smoke evolution.

Applications: Cabinets and cases, particularly for domestic and industrial instruments, e.g. TV cabinets, food mixers, telephone sets, vacuum cleaners. Vacuum formings for baths, shower trays, etc. Extruded into pipe. Used in preference to PVC for high (50-70°C) or low (<20°C) temperatures. Mouldings may be electroplated for bathroom or automotive applications.

Many grades of ABS are manufactured by a number of companies including General Electric (*Cycolac*), Bayer (*Novodur*), Dow (*Magnum*), Monsanto (*Lustran*), Huntsman Chemical Company Australia Ltd. (*Astalac*), and BASF (*Terluran*). General Electric alone produces about 70 grades of *Cycolac* exhibiting a very wide range of properties such as medium, high and super impact, flame retardant, high heat, transparent, static dissipative, and alloys with other polymers. *Cycolac* grades 'GSM' and 'T' were recommended as they exhibit a range of properties appropriate to the VISEM, particularly high impact strength (equivalent grades now are GPM 4700 and GPM 5600 respectively). The range of grades available offered ample scope for 'fine tuning' depending on which material attributes became significant during the development phase of the project.

5. Other Plastics Materials

A number of other plastics materials have been used for special items in the VISEM during the development phase as follows:

Power Supply Housing

This assembly has been made from unplasticised poly (vinyl chloride), (UPVC), as a matter of expediency and economy since two of its main components (items 3 and 5, Table 3) can be made from standard 'off the shelf' piping. It is expected that a relatively large number of these assemblies will be produced as it is an expendable item with a service life dependant on the life of the batteries (maximum 90 days). Although UPVC has inferior low temperature impact strength to ABS this is not considered important for this assembly as it will be well protected and supported within the VISEM. However there remains a further disadvantage of UPVC in that it gives off corrosive fumes (hydrochloric acid) during melt processing and this determines that any injection moulding dies required to manufacture the other plastics items in the Power Supply Housing will need to be made from stainless steel. Alternatively there is no technical reason why UPVC and ABS cannot be used together in this assembly. The economics of this choice will need to be assessed prior to commencing commercial production of the VISEM.

Washer

The function of the washer (item 3 of Surface Position Marker, Table 3) is to prevent any excess adhesive from the cap/body joint adhering other items below this joint. Polypropylene has been chosen because of its poor bonding properties and relatively good machineability. Polyethylene and polytetrafluoroethylene (eg. *Teflon*) have poorer bonding properties but are difficult to machine.

Packing

The function of the packing (item 16 of Surface Position Marker, Table 3) is to fill the space between the photoflash payload and the compression disc. Polystyrene foam has been chosen as it will not be subject to the hydrostatic pressure resulting from immersion underwater and otherwise fulfills all requirements of this application.

Tether Line Pack

This package (item 17 of Surface Position Marker, Table 3) is a commercially available item containing polyester string coated with PVA to cause the string to adhere to itself when wound on a mandrel.

Table 3: VISEM Polymeric Components

Drawing Title	Drawing No.	Item No.	Description	Material Selected
Sub-surface System Assy.	8/09/M3/6	1	Base plate & centre tube assy.	ABS
" " " "	"	8	Container body	Divinycell with GRP skin
Surface Position Marker assy.	8/09/M3/4	1	Float	Divinycell H130 foam
" " " "	"	2	Cap	ABS
" " " "	"	3	Washer	Polypropylene
" " " "	"	4	Washer	ABS
" " " "	"	5	Body	ABS
" " " "	"	7	Connector	ABS
" " " "	"	8	Tail assy.	ABS
" " " "	"	16	Packing	Styrene foam
" " " "	"	17	Tether line pack	Polyester string
Electronics Housing	8/09/M5/14	1	Body	ABS
" "	"	2	Micro switch disc	ABS
" "	"	3	Micro switch plate	ABS
" "	"	4	Connector spigot	ABS
" "	"	5	Connector housing	ABS
" "	"	6	Top closure	ABS
" "	"	7	Conduit	ABS
Power Supply Housing	8/09/M5/5	1	Connector sleeve	UPVC
" " "	"	2	Top closure	UPVC
" " "	"	3	Conduit	UPVC
" " "	"	4	Conduit base	UPVC
" " "	"	5	Body	UPVC
" " "	"	6	Base closure	UPVC

Connector

The connector (item 7 of Surface Position Marker, Table 3) is required to encapsulate two brass pins to enable an electrical connection between the electronics housing and the SPM and to mechanically take the thrust of the SPM launch. In the production phase it is intended that this item will be injection moulded using ABS but to avoid the cost and risk (of design change) in producing a die in the development phase, connectors were cast using epoxy resin. During this prototyping phase 42 connectors were cast using six moulds produced from Dow Corning RTV E Mould Making silicone rubber. (Earlier moulds had been produced from Rhodorsil RTV 585/CAT 60R silicone rubber but this material was too soft and did not maintain its shape during the exothermic curing reaction and problems were also encountered due to air inclusions.) Various modifications to technique and formulation were made during the production of connectors 1 to 12 mainly due to problems with air inclusions and maintaining dimensional integrity. The procedure was basically standardised for connector No's 13 to 42 and it was these which were used in the March 1993 sea trials. Details of the final casting procedure and epoxy resin system used is shown in Table 4.

Table 4: Casting of VISEM Electrical Connector

Resin Type (100 parts)	Araldite Weight (g)	Hardener* Type (40 parts)	Hardener Weight (g)	Additional Hardener (4.2 parts)	Hardener Weight (g)	Notes
Araldite M*	114.3	HY5160*	45.7	HY956*	4.8	* Ciba-Geigy product
	24.0**					** Extra added in ratio 5 : 1 to react with HY956
Totals	138.3		45.7		4.8	

METHOD

1. Ensure mould is clean then insert brass pins.
2. Weigh out ingredients & mix thoroughly avoiding entrapment of air as far as possible.
3. Partly fill mould then probe air bubbles from undercut at base of mould.
4. Complete filling of mould to ~3 mm from top.
5. Place mould in oven at ~70°C for ~24 h to cure resin.
6. Roll back top of mould & extract connector.

On almost all occasions these items failed to withstand the launch forces during sea trials and were extensively damaged. Additionally the connectors were difficult to hold in the lathe chuck during machining (due to lack of stiffness) and this led to problems in maintaining the tolerance band of 0.15 mm. If for some reason connectors were to be produced by this method in the future (rather than using ABS) formulation changes and perhaps better post curing would be required to overcome the above problems.

6. Float Development

During the initial development phase of the VISEM the following design criteria were established for the float (buoyancy collar) of the SPM.

- The float is required to maintain buoyancy at a maximum depth of 90 m for 90 days, bring the flare to the surface after release, float during flare operation and, ideally, burn away and allow the indicator to sink after operation.
- Compression strength required is 1100 kPa (90 m immersion in sea water plus 20 m safety factor).
- Float to provide maximum possible buoyancy.

- Very low water absorption.
- Flare burns for 30 s at a white heat in a metal tube.
- Shape designed to give fastest possible rise time.
- Attached (probably adhered) to a central plastics tube.
- Float may stand alone or be required to give structural support to the outer shell. Conversely, the outer shell may give some structural support, allowing the use of a lower compressive strength foam.

In developing the float three options were explored, i.e. fabricating from *Divinycell* closed cell PVC foam, moulding with closed cell polyurethane (PU) foam, and moulding a hollow float from solid plastics material.

6.1 Fabrication from foam sheet material

Foams which were considered to have properties relevant to the above design criteria are shown in Table 5. All give the required buoyancy, have low water absorption and are amenable to bonding to the central plastics tube of the flare. A number of these materials are normally supplied in sheet form requiring the buoyancy collar to be fabricated by bonding and machining sections. However the possibility of moulding the required shape could be negotiated with some companies.

Divinycell and *Airex* are similar closed cell PVC foams, both imported in sheet form, and both available in grades of adequate compressive strength. These materials are self extinguishing and therefore might have been able to fulfil the opposing requirements for the indicator to remain afloat during the flare period but to burn away and sink after operation. *Divinycell* HCP grades are specifically designed for sub-sea applications and a special adhesive (*Divilette*) is marketed for bonding the material. Diab-Barracuda fabricated a number of floats using *Divinycell* grade H-130 and these were used successfully in prototype trials (short term immersion). It was found necessary to coat the floats to reduce drag and hence rise time. The floats did not burn sufficiently to allow the SPM to sink after operation and furthermore the burning foam reduced the flare performance. This problem was overcome by use of a special paper insert to give a chimney effect but burning of the foam was further reduced.

Styrofoam Floormate (polystyrene) is cheap, has excellent buoyancy, very low water absorption, combustibility that can be reduced by addition of a fire retardant and has excellent bondability. However no work was undertaken with this material as the compressive strength (700 kPa min.) was insufficient.

Firesafe (phenolic) has very low combustibility and excellent heat resistance but has a high open cell content making it prone to water absorption under high pressure and furthermore development of this product at the time had not proceeded to the point where material of known high compressive strength was available.

Table 5: Foam Properties

Foam description	Grade	Density (kg/m ³)	Water absorption	Combustibility	Bondability	Comp. strength (kPa)
<i>Airex</i> (Plastrol Trading) Poly (vinyl chloride) closed cell, cross-linked		55 75 100	0.9% v/v (7 days) 0.6% v/v (7 days)	Self extinguishing	Yes	750 1200 1900
<i>Divinycell</i> (Diab-Barracuda) Poly (vinyl chloride), closed cell, cross-linked	H-80 H-130 HCP30	80 130 200	0.046 kg/m ² 0.03 kg/m ² <0.1% @ 100 h	Self extinguishing Self extinguishing Self extinguishing	Yes (<i>Divilette</i>) Yes (<i>Divilette</i>) Yes (<i>Divilette</i>)	1000-1200 2500 4100-4400
<i>Styrofoam Floormate</i> (Dow) polystyrene closed cell	700	45	0.1% v/v max.	Flame retarded but will burn	Yes	700 (min.)
<i>Firesafe</i> (Insulco) Phenolic, 50% closed cell		35 120 200	2% (ASTM C-272)	Very low	Yes	100 550±200 ?
Polyurethane, closed cell		50 130		Burns but can be flame retarded	Yes	350 1100

Polyurethane was used in an attempt to mould floats as described in the following paragraph.

6.2 Moulding with Polyurethane Foam

Although a successful prototype had been developed by fabricating *Divinycell* foam it was anticipated that a considerable saving in unit cost might be achieved by moulding the float from a suitable grade of closed cell polyurethane foam. Accordingly an aluminium mould (MRL drawing No.3863-01) was constructed and a series of floats moulded using various grades of *Aptane* polyurethane foam ingredients as supplied by Ariel Industries Pty. Ltd. [4] and a mould release agent provided by Glenmount Pty. Ltd. [5]. Although the compressive strength of standard grades of polyurethane foam is much lower than the 1100 kPa required by the float there is a more or less linear relationship between density and compressive strength and by very extended extrapolation of density/compressive strength data [6] a compressive strength of 1100 kPa at a density of about 130 kg/m³ was considered feasible. Further increase in strength of a moulded foam article can be achieved by encouraging the 'integral skin effect' (mainly by formulation) whereby a very dense skin is formed against the walls

of the mould whilst the interior has a foam structure. A series of floats was moulded as detailed in Table 6 and some were further reinforced by coating with polyurethane adhesive or epoxy resin. The hydrostatic compressive strength of suitable floats was then determined in a compression chamber at 1034 kPa (150 psi) and any increase in weight due to water absorption measured. It can be seen from Table 6 that float A10 (density approximately 208 kg/m³) showed promise with only a one gram increase in weight after the pressure test and an 18 gram increase when retested after five deliberate perforations of the outer skin. It is feasible that, with further experimentation, floats meeting the performance criteria could be produced by this procedure.

6.3 Injection Moulding from Plastics Material

This option was developed to meet the RAN environmental requirement to recover the SPM after firing. To enable this it was necessary for the SPM to sink after operation and remain tethered to the VISEM cradle which could later be brought to the surface together with any spent SPM's. Since burning of the foam float during operation of the flare had not been achieved, and its fragmentation after operation was deemed to be environmentally unacceptable, a hollow plastics float was designed such that it would fill with water after operation and sink.

Prototypes were machined from UPVC because ABS was not available 'off the shelf' in a suitable size and special extrusion was prohibitively expensive. However, in the production phase it is anticipated that the floats would be injection moulded using ABS as it is lighter and has a higher impact strength than UPVC. Although the prototypes have not been operationally tested at this time the hollow moulded float is expected to be successful as it does not incorporate any untested features.

7. Adhesives

Adhesives are to be used for assembly of the various plastics components of the VISEM and this requirement was used as one of the selection criteria for the plastics materials (paragraph 3). ABS is readily assembled using suitable epoxy or cyanoacrylate adhesives or solvent cements based on either methyl ethyl ketone, methyl isobutyl ketone, tetrahydrofuran or methylene chloride. A proprietary solvent cement is marketed by Dura-Wills [7] (manufacturer of ABS pipe) which is formulated to withstand the same working conditions as the rest of the system and correctly made joints made using this method are claimed to be stronger than either pipe or fitting.

Table 6: VISEM Float Development (Polyurethane Foam)

Float No.	Material A	(pbw)	(g)	Material B	(pbw)	(g)	Moulding Notes	Float Wt. (moulded) (g)	Density (Note 1) (Kg/m ³)	Float Coating	Float Wt. (coated) (g)	Performance
A1	Aptane DP 2905/2	100	75	Aptane B 900	118	88.5	Mould not filled	143		READD 128M (Note 2)	154	Pressure tested @ 150 psi/5 min. weight = 589 g
A2	Aptane DP 2905/2	100	112.5	Aptane B 900	118	132.7	Filled except top corner	221	170	Nil		Not tested
A3	Aptane DP 2905/2	100	127.5	Aptane B 900	118	150.4	Filled except top corner	256	197	Nil		Pressure tested @ 150 psi/5 min. weight = 301 g Tested for burning characteristics.
A4	Aptane DP 2905/2	100	90	Aptane B 900	118	106.2	Not quite filled	174	134	Epoxy resin (Note 3)	186	Pressure tested @ 150 psi/5 min. weight = 231 g
A5	Aptane P 175	100	100	Aptane B 900-1	103	103	Filled except top corner	174	134	Epoxy resin (Note 4)	200	Submerged @ 90 m in Jervis bay.
A6	Aptane P 175	100	80	Aptane B 900-1	103	82.4	Mould heated to 45°C	131	101	Epoxy resin (Note 5)	?	Foam & coating fractured, weight = 926 g. Pressure tested @ 150 psi/5 min.
A7	Aptane DP9303/8 Note 6	100	80	Aptane B 900	160	128	Mould heated to 30°C	177		Nil		Foam & coating fractured, weight = 588 g.
A8	Aptane DP9303/8	100	110	Aptane B 900	160	176	Mould not filled	240		Nil		Not tested (incomplete moulding, surface bubbles)
A9	Aptane DP9303/8	100	130	Aptane B 900	160	208	Mould heated to 50°C	292	225	Nil		Not tested (incomplete moulding, surface bubbles)
A10	Aptane DP9303/8	100	120	Aptane B 900	160	192	Mould heated to 50°C Note 7	271	208	Nil		Test 1-pressure tested @ 150 psi/1 min. weight = 272 g. Test 2-skin perforated 5 places then pressure tested @ 150 psi/1 min. weight = 289 g.

Notes

- 1 Based on filled mould volume of 1300 cm³
- 2 Polyurethane adhesive (1 coat)
- 3 Ciba Geigy Epoxy resin GY 6010 with amine hardner LC 177 in ratio 10:4 (1 coat)
- 4 As per note 3 (2 coats)
- 5 Expanded after curing @ 100°C & wouldn't fit pressure chamber
- 6 International Paints 'Intershield' EGA100/EGA103 (2 coats black).
- 7 22 g Forane 11 blowing agent added (~7%)

8. Conclusions and Recommendations

A design profile for the VISEM has been drawn up with a view to selecting appropriate polymeric materials for its construction. The requirement that the device withstand being submerged in sea water to a maximum of 90 m for 90 days and for the SPM to rise to the surface in a limited time and function reliably was of paramount importance. To enable cheap mass production of components by injection moulding and assembly with adhesives, ABS was selected as the optimum plastics material to fulfil these requirements. This choice was supported by a creditable performance of the material during sea trials of the VISEM.

During the development phase UPVC was used as an alternative to ABS for the construction of the Power Supply Housing of the VISEM. This choice was based on material availability and the fact that the superior impact strength of ABS would not be required by this assembly because it is protected within the VISEM. However stainless steel dies will be needed if UPVC is to be injection moulded and the economics of this choice will need to be assessed prior to commencing commercial production of the VISEM.

In developing the float of the SPM three options were explored, i.e., fabrication from *Divinycell* closed cell PVC foam, moulding with closed cell PU foam and moulding a hollow float from plastics material. Although floats used successfully in the sea trials were fabricated from *Divinycell*, and some promise was shown by the moulded PU option, the final choice will be for a hollow plastics float due to the requirement for the float to sink after operation of the SPM.

With the original design profile remaining basically unchanged during the development phase of the project the VISEM system evolved through a number of variations culminating in a system proposed for manufacture as shown by Figure 1. Table 3 indicates the main sub assemblies of the VISEM and lists the items made from polymeric materials.

10. References

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2. Feasibility study for the development of a visual firing indicator for the Stonefish Exercise Mine by Peter Ramsay (MRL).
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4. Ariel Industries Pty. Ltd., 26 Kembla Street, Cheltenham, Victoria 3192, Australia. (Contact Mr. Gerard Murray Telephone (03) 584 3966).

5. Glenmount Pty. Ltd., 32 Cahill Street, Dandenong 3175, Victoria, Australia.
(Contact Mr. Ian Urquhart Telephone (03) 794 5877).
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Visual Indicator-Stonefish Exercise Mine,
Polymeric Materials Selection

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ABSTRACT

The RAN has a requirement for a real time visual mine firing indicator (VISEM) for the Stonefish Exercise Mine (SEM). This device is an alternative indicator to the towed receiver which is not available to all ships that exercise with the SEM due to its limited availability and high cost.

This report documents aspects concerning the choice of polymeric materials for the VISEM. A design profile was drawn up and the critical parameters used in the PLASCAMS 'Plastics Computer Aided Materials Selector' program to indicate suitable plastics materials for production of components of the VISEM. Acrylonitrile Butadiene Styrene (ABS) was selected as having the optimum properties to meet the design profile that included requirements for hydrolytic stability, toughness over a wide temperature range and ease of production by injection moulding and assembly with adhesives.

The report also includes information about other polymers and adhesives used in the device including some used to test concepts or selected as a matter of expediency during the development phase of the project.